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Research on the Evaluation Method of Green Construction Project Based on Grey Entropy Correlation

Wen Zhao[1*], Qian Wu[1], and Xuetao Wen[1]

[1] School of civil and environmental engineering, Anhui Xinhua University, Hefei, Anhui, 230088, China

[*]Corresponding author's e-mail:316200468@qq.com

Abstract. This paper proposes a bid evaluation method based on grey entropy correlation degree for green construction projects. The first, the evaluation index system of a green construction project is constructed based on the technical requirements of a green construction project. The grey entropy method is also used to eliminate the influence of subjective empowerment on the evaluation result. This removal is intended to build the evaluation model based on the grey relational degree of entropy weight, and select the winning bidder by calculating the correlation degree of each bidder and the ideal scheme. Finally, an engineering example shows this method can be applied to the process of evaluating bids of green construction projects. This method can help the tenderer select the winner of the green construction project more objectively and reasonably.

1. Introduction

The construction project needs to consume considerable land, water, materials, and energy resources in the construction process, which brings a certain degree of damage to the natural environment. Therefore, it is significant to advocate green construction in the construction process. In October 2011, China's ministry of housing and urban-rural development promulgated the "green construction evaluation standard for construction projects." The Bidding and the tendering are the most common ways of project procurement in China. Therefore, it is of great application value to study the comprehensive evaluation system of green construction.

At present, several studies on the evaluation methods of green construction projects have been conducted by domestic scholars. Most of these studies focus on investigating the evaluation system of green construction projects or on the evaluation methods of general engineering construction projects. In the study on the evaluation system of green construction projects, scholars have analyzed the evaluation index system of green construction projects from three perspectives of qualification, technology, and economy [1]–[4]. Considerable research results have been obtained in evaluation method research. Cheng Wei et al. improved the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method to evaluate bids [5], while Zhang Shilian et al. constructed the evaluation model through the theory of fuzzy sets [6]. In addition, the D-S evidence theory and the Triangular Fuzzy Analytic Hierarchy Process (TFAHP)-TOPSIS combined methods [7], the Analytic Hierarchy Process (AHP) [8], and the grey clustering method [9] are all applied in the bidding evaluation process. Grey theory is also applied in the process of bid evaluation [10], but most scholars adopt subjective weighting method in the application process, making the final bid evaluation result slightly inaccurate.

On the basis of literature review and research on a large number of bidding documents, this paper selects the bidding evaluation factors of green construction projects and obtains the bidding evaluation system by sorting them out. Simultaneously, a grey relational bid evaluation model based on entropy is introduced, and the degree of influence of each evaluation index on the whole model is calculated by using the entropy weight method. A grey relational bid evaluation model is constructed to determine the correlation degree between each bidder and the owner's ideal bidder to sort the bidders. This method eliminates the influence of subjective weight on the evaluation result, and the grey entropy model is more objective and reasonable in the process of green construction project evaluation.

2. Green construction project evaluation index system

This paper discusses the qualifications, technical standards, and business model of the three-point building green construction project bid evaluation system. This system not only embodies the tender offer, construction plan, and so on, but also the characteristics of the general project construction bid assessment, including the green construction on the saving energy, land, water, and material, as well as environmental protection requirements into technical standard parts. The consideration in this study is determined using the 18 bid assessment as secondary indices to build a comprehensive, reasonable, and feasible green construction project bid evaluation index system, as shown in Table 1.

Table 1. Evaluation index system of green construction projects

	Level indicators	Secondary indicators
		Level of qualification (B_{11})
		Similar engineering experience (B_{12})
	Qualification (B_1)	Corporate financial position (B_{13})
		Project manager performance (B_{14})
		Corporate reputation (B_{15})
		Construction plan (B_{21})
		Construction period (B_{22})
		Safety-ensuring measures (B_{23})
Evaluation index system (B)		Quality control measure (B_{24})
	Technology (B_2)	Environmental protection(B_{25})
		Water-saving schemes and measures (B_{26})
		Land saving programmes and measures (B_{27})
		Material saving plans and measures (B_{28})
		Energy-saving plans and measures(B_{29})
		Bid price (B_{31})
	Business (B_3)	Rationality of unit price of sub-projects (B_{32})
		rationality of capital flow statement (B_{33})
		Preferential terms(B_{34})

3. Determination of index weight

Entropy was originally introduced into information theory by a mathematician named Shanon from thermodynamics, after which information entropy became a reliable method for weight determination [11]. The weights calculated by entropy are deemed to be more objective and ensures impartiality in the evaluation results. The steps in using entropy to calculate the weight of indicators are as follows:

(1) Construct evaluation sequence

The initial index value sequence consisting of n evaluation indices provided by m bidding units is constructed is denoted as X_{ij}.

$$X_{ij}=[X_{11},X_{22},...,X_{ij})] \quad i=1,2,...,m \quad j=1,2,...n$$

(2) Standardized treatment of indicators

Its value part in the evaluating index, which in this case is the bigger the better, such as enterprise qualification, is defined as the efficiency index. When its value is small, such as bid price quotations, we define it as cost indicators. According to the following method for the standardized treatment of indicators, the index is eliminated because of the influence of the unit of measurement for different indicators.

When the indicator is a benefit indicator

$$X'_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (j=1,2,...n) \quad . \tag{1}$$

When the indicator is a cost-based indicator

$$X'_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_{i=1}^{m} \frac{1}{x_{ij}}} \quad (j=1,2,...n) \quad . \tag{2}$$

(3) Find the difference of evaluation index G_j

$$G_j = 1 + \frac{1}{Ln(m)} \sum_{i=1}^{m} X'_{ij} Ln(X'_{ij}) \quad (j=1,2,...n). \tag{3}$$

(4) Calculation of entropy β_j

$$\beta_j = G_j / \sum_{i=1}^{m} G_j \quad . \tag{4}$$

4. Construction of bid evaluation model

4.1. Dimensionless treatment of the index value

In the evaluation indicator system, the enterprise qualification, quotation, construction period, and other indicators have different dimensions. The effect of different dimensions on the evaluation decision can be eliminated by using the dimensionless treatment of the characteristic values of each indicator and treating the index value as the number between 0 and 1. The matrix after the index processing is denoted as X_{ij} .

$$X''_{ij} = \frac{x_{ij} - \overline{X_j}}{\sigma_j} \quad (i=0,1,2,...,m \quad j=0,1,2,...n) \tag{5}$$

Among them, $\overline{X_j} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}$ (i=0,1,2,...,m j=0,1,2,...n)

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(x_{ij} - \overline{X_j})^2}{m}} \quad (i=0,1,2,...,m \quad j=0,1,2,...n)$$

4.2. Determination of reference sequence

From the data of relevant indicators provided by m bidders, the minimum value of construction period and bidding quotation is selected as the optimal bidding index value, while the maximum value of other indicators is chosen as the optimal value. These optimal values constitute the reference sequence X_{0j}.

$$X_{0j}=[X_{01},X_{02},...,X_{0n}]^T \quad (j=1,2,...n)$$

The constructed X_{0j} and bidding index values of each bidding unit are standardized and jointly constitute the eigenvector matrix P:

$$P=\left(X_0^" \quad X_1^" \quad X_2^" \quad \cdots \quad X_n^"\right)=\begin{pmatrix} X_{01}^" & X_{11}^" & X_{21}^" & \cdots & X_{m1}^" \\ X_{02}^" & X_{12}^" & X_{22}^" & \cdots & X_{m2}^" \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ X_{0n}^" & X_{1n}^" & X_{1n}^" & \cdots & X_{mn}^" \end{pmatrix}.$$

4.3. Calculation of correlation coefficient
The correlation coefficient refers to the degree of difference between the optimal value of the scheme (reference sequence) and the index data provided by the tenderer (evaluation sequence). The formula for calculating the correlation coefficient ξ_{ij} is as follows:

$$\xi_{ij}=\frac{\Delta\min+\delta\Delta\max}{\Delta ij+\delta\Delta\max} \quad (6)$$

Among them, $\Delta\min=\min i \min j\left|X_{ij}^" - X_{0j}^"\right|$,

$\Delta\max=\max_i \max_j\left|X_{ij}^" - X_{0j}^"\right|$

$\Delta ij=\left|X_{ij}^" - X_{0j}^"\right|$

δ is the resolution coefficient, generally 0.5.

4.4. Calculation of grey correlation degree
The R_i value can be calculated by using the calculated ξ_{ij} value and β_j value

$$R_i=\xi_{ij} * \beta_j \quad . \quad (7)$$

The larger the grey correlation degree R_i is, the greater the degree of correlation between the bid value Xi and the ideal bid value X_0. Thus, the bidders can be selected according to the rank of correlation degree.

5. Case analysis of bid evaluation
A certain green construction project in Hefei is invited for construction bidding, and a total of A, B and C serve as qualified bidding units to participate in the bidding. After receiving the bidding documents submitted by each bidding unit, the construction unit will sort out the index data, as shown in Table 2.

Table 2. Bidder bidding statistics table

Bidder / Indicators	Bidder A.	Bidder B.	Bidder C.
B_{11}	70	85	90
B_{12}	83	90	87
B_{13}	86	80	92
B_{14}	88	83	87
B_{15}	80	82	70
B_{21}	90	72	81
B_{22}	348	380	355
B_{23}	88	85	68
B_{24}	72	90	84

B_{25}	89	76	94
B_{26}	80	90	85
B_{27}	75	80	65
B_{28}	85	80	75
B_{29}	75	70	90
B_{31}	3345.8	3548.2	3673.5
B_{32}	82	65	90
B_{33}	65	82	88
B_{34}	75	92	85

(1) Determine the weight of indicators

According to Formula (1)–(4), calculate the data of each indicator of bidders in Table 2, and acquire the entropy weight value of each indicator as shown in Table 3.

Table 3. Entropy weight of each index

Indicators	B_{11}	B_{12}	B_{13}	B_{14}	B_{15}	B_{21}	B_{22}	B_{23}	B_{24}
Entropy	0.089	0.009	0.026	0.005	0.037	0.066	0.011	0.099	0.068
Indicators	B_{25}	B_{26}	B_{27}	B_{28}	B_{29}	B_{31}	B_{32}	B_{33}	B_{34}
Entropy	0.063	0.018	0.059	0.021	0.093	0.012	0.143	0.127	0.056

(2) Determine the bid assessment ideal index sequence for X_0=(90, 90, 92, 88, 82, 90, 348, 88, 90, 94, 90, 80, 85, 90, 3345.8, 90, 88, 92)^T.

(3) Use formula (5) to standardize the index data and the sequence of evaluation ideal indicators to obtain matrix P. The processing results are shown in Table 4.

Table 4. Results of standardized treatment

Indicators \ Bidder	Reference sequence	Bidder A.	Bidder B.	Bidder C.
B_{11}	1.06	0.370	0.296	0.333
B_{12}	1.05	0.345	0.316	0.338
B_{13}	1.06	0.365	0.353	0.282
B_{14}	1.03	0.293	0.366	0.341
B_{15}	1.06	0.344	0.293	0.363
B_{21}	1.05	0.314	0.353	0.333
B_{22}	1.05	0.341	0.364	0.295
B_{23}	1.02	0.354	0.333	0.313
B_{24}	1.04	0.319	0.298	0.383
B_{25}	1.07	0.350	0.330	0.319
B_{26}	1.08	0.346	0.274	0.380
B_{27}	1.08	0.277	0.349	0.374
B_{28}	1.08	0.298	0.365	0.337
B_{29}	1.08	0.370	0.296	0.333
B_{31}	1.07	0.345	0.316	0.338
B_{32}	1.08	0.365	0.353	0.282
B_{33}	1.04	0.293	0.366	0.341

B_{34}	1.03	0.344	0.293	0.363

(4) According to Formula (6), the grey correlation value is calculated, and the results are shown in Table 5.

Table 5. Correlation values of indicators

Indicators \ Bidder	Bidder A.	Bidder B.	Bidder C.
B_{11}	0.342	0.410	1.000
B_{12}	0.334	0.334	0.539
B_{13}	0.500	0.500	1.000
B_{14}	1.000	0.346	0.726
B_{15}	0.763	0.763	0.349
B_{21}	1.000	0.333	0.500
B_{22}	1.000	0.345	0.706
B_{23}	1.000	0.782	0.350
B_{24}	1.000	0.337	0.433
B_{25}	0.650	0.417	1.000
B_{26}	1.000	0.333	0.500
B_{27}	1.000	0.604	0.433
B_{28}	1.000	0.500	0.333
B_{29}	0.410	0.675	1.000
B_{31}	1.000	0.450	0.335
B_{32}	0.615	0.429	1.000
B_{33}	0.342	0.412	1.000
B_{34}	0.334	0.334	0.550

(5) Calculate the correlation degree of the three bidders by using Formula (7), as shown in Table 6.

Table 6. Calculation results of each bidder's correlation degree

Bidder	Bidder A.	Bidder B.	Bidder C.
R_i	0.663	0.488	0.744

The calculation results show that the R_i value of bidders C is the largest, indicating that the scheme of bidders C and the ideal scheme have the highest degree of correlation. Thus, the order in selecting bidders is C, A, and B.

6. Conclusion

In this paper, the qualification, business and technology combined with the technical requirements of green construction projects were used to select objectively the green construction project bid evaluation index. The use of the grey correlation model using grey entropy method weakened the subjective values. The influence of the method was evaluated based on the results and the analysis of the actual engineering example. The results indicate that the method is more objective and offers fair evaluation, which could also promote domestic green construction projects to some extent.

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